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<b>14. ABSTRACT</b> This test operations procedure (TOP) is intended to furnish basic testing information to facilitate test planning, conducting and reporting, and to achieve standardized chemical protective performance testing of protective masks and accessories using the Simulant Agent Resistance Test Manikin (SMARTMAN). It describes test facilities, equipment, and procedures to be used for SMARTMAN testing and evaluating protective mask technical performance and safety aspects. Biological and radiological protective performance testing of the mask systems is not included in this TOP.					
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U.S. ARMY TEST AND EVALUATION COMMAND  
TEST OPERATIONS PROCEDURE

Test Operations Procedure 08-2-109  
DTIC AD No.

16 September 2013

SIMULANT AGENT RESISTANCE TEST MANIKIN (SMARTMAN) TESTING OF  
PROTECTIVE MASK SYSTEMS

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## 1. SCOPE.

### 1.1 Background.

The Simulant Agent Resistance Test Manikin (SMARTMAN) fixture and exposure chamber were developed to test individual protection (IP) respiratory equipment as a system. IP respiratory equipment is placed on a human manikin head form inside an environmental control chamber. During testing, the IP equipment is made to function by means of artificial respiration and then challenged with liquid or gaseous chemical warfare agents (CWAs) or simulants. The test fixture monitors the challenge concentration and the concentrations of agent or simulant that have broken through the IP respiratory equipment (from penetration, permeation, or both), thereby providing a measure of the ability of the equipment to protect the wearer from chemical exposure.

### 1.2 Purpose.

a. This test operations procedure (TOP) details whole-mask SMARTMAN testing with CWA or simulant liquid/vapor (L/V) or vapor only challenges which are conducted on new, previously worn, or preconditioned IP masks and mask systems (hereafter referred to as masks). Any simulants used must have an approved agent/simulant correlation or relationship, or testing with the simulant will not be performed. Data collected from the SMARTMAN test is used to determine the CWA resistance of the candidate mask and to evaluate protective performance in contaminated environments. **NOTE:** Although the main purpose is to describe acquisition and related testing in the SMARTMAN fixture, these procedures can be used for other whole-mask SMARTMAN testing in chemically contaminated environments with non-military or first responder applications.

b. SMARTMAN testing is a System Level Test per the Overarching IP Test and Evaluation (T&E) strategy. Even though SMARTMAN tests a component of a complete ensemble, it still tests a full mask system. The test items will be evaluated in accordance with (IAW) the requirements listed in the performance specification, the capabilities documents [the initial capability document (ICD), the capability development document (CDD), or the capability production document (CPD)], the concept of operations (CONOPS), and failure definition/scoring criteria (FD/SC). The operational test agency (OTA) evaluation plan (OEP) and the test and evaluation master plan (TEMP) will be used to determine the overall test structure, data required, and criteria and analysis to be used.

### 1.3 Limitations.

a. This TOP does not cover chemical, biological, and radiological (CBR) protective mask testing using human participants, which is described in TOP 08-2-110<sup>1\*</sup>.

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\*Superscript numbers and letters correspond to those in Appendix D.

- b. This TOP describes standard procedures for SMARTMAN chemical protective performance testing of CBR protective masks and accessories. Biological and radiological protective performance testing of the entire mask systems are not included in this TOP.
- c. Test data using simulants for agents cannot be used without establishment of the agent/simulant relationship.
- d. The CWA protective performance criteria and implementation of the procedures of this TOP are not related to the safety criteria of U.S. Army Regulation (AR) 385-10<sup>2</sup>, Department of the Army (DA) Pamphlet (PAM) 385-61<sup>3</sup>, Military Standard (MIL-STD)-882E<sup>4</sup> or other local regulations governing the safety, handling, storage, and disposition of chemically or biologically contaminated equipment.
- e. Although not specifically described, the test procedures in this TOP may be extended to SMARTMAN testing using toxic industrial chemicals (TICs), toxic industrial materials (TIMs), battlefield contaminants (BFCs), and non-traditional agents (NTAs). Modifications (see Paragraph 1.3.f) may be required for tests with challenge materials other than CWAs.
- f. The test procedures described herein may be required in a test plan. The procedure may require modification for unique items or materials or to satisfy specific testing requirements as delineated in an OEP, performance specification, ICD/CDD, or a TEMP. However, alteration of this procedure will be made only after full consideration of the possible effect the changes may have upon the reliability and validity of the data to be obtained and will be coordinated with all concerned organizations in advance.

## 2. FACILITIES AND INSTRUMENTATION.

### 2.1 Facilities.

Facilities, instrumentation, and safety procedures used for chemical agent testing are strictly controlled. Additional discussion and requirements for facilities and instrumentation are included in the test procedures (Paragraph 4).

<u>Item</u>	<u>Requirement</u>
Chemical laboratory and chemical agent storage facility.	Constructed to ensure safe and secure storage, handling, analysis, and decontamination of research, development, test and evaluation (RDT&E) quantities of chemical agents and/or simulants used for surety material.
SMARTMAN fixture and exposure chamber (test system).	Constructed to house the test item during agent or simulant dissemination. Will include the environmentally controlled test chamber, a SMARTMAN head form with a breather pump, agent/simulant liquid and vapor disseminators, and all instrumentation necessary to perform SMARTMAN testing, including sampling systems and data recorders.

<u>Item</u>	<u>Requirement</u>
Engineering control system.	Test areas in laboratories and chambers must be equipped with climatic controls that allow air temperatures and air-exchange rates to be maintained at prescribed levels throughout the testing period.
Medical clinic.	The clinic will have medical authorities and equipment required to treat accidental human exposure to chemical agent, NTAs, TICs, TIMs, BFCs, or overexposure to simulant. The staff will include emergency medical technicians (EMTs) qualified in advanced life support.

## 2.2 Instrumentation.

Permissible error measurement values are minimum requirements. Actual instrumentation may have greater precision and accuracy; actual values will be reported.

<u>Parameter</u>	<u>Measuring Device</u>	<u>Permissible Error of Measurement</u>
Chemical agent vapor detection.	Near real-time (NRT) instrumentation, e.g., MINICAMS <sup>®</sup> (a miniature, automatic, continuous air-monitoring system, OI Analytical, division of OI Corporation, College Station, Texas); Miniature Infrared Analyzer <sup>®</sup> (MIRAN <sup>®</sup> , Thermo Fisher Scientific, Waltham, Massachusetts); sulfur and/or phosphorus analyzers; or equivalents of these instruments. <sup>**</sup>	Quality control (QC) challenge recovery must be within $\pm 15$ percent of the expected value.
Chemical agent liquid application.	Calibrated syringe pump dispenser or equivalent.	Actual average dispensed mass must be within $\pm 10$ percent of the calculated value for the mass of the agent.

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<sup>\*\*</sup>The use of brand names does not constitute endorsement by the Army or any other agency of the Federal Government, nor does it imply that it is best suited for its intended application.

<u>Parameter</u>	<u>Measuring Device</u>	<u>Permissible Error of Measurement</u>
Vapor dissemination system.	A computer-controlled syringe pump for dissemination into a heated source to introduce vaporized agent/simulant into the test chamber.	Concentration of disseminated agent must be within $\pm 20$ percent of the theoretical target concentration.
Chemical agent mass from vapor and liquid samples ( $\mu\text{g}$ ).	Gas chromatograph (GC); liquid chromatograph (LC); flame ionization detector (FID); flame photometric detector (FPD); mass spectrometer (MS), or equivalent.	$\pm 15$ percent of calibration standard.
Chamber air temperature.	Thermocouple or other.	$\pm 0.5^\circ\text{C}$ .
Relative humidity (RH).	Hygrometer or other.	$\pm 2$ percent RH.
Photographs.	Still color camera.	Adequate to document any abnormalities or damage to the test items.

### 2.3 Test Controls.

<u>Parameter</u>	<u>Tolerance</u>
Positive control mask.	Must be a full-face mask or escape hood certified for use in industry for chemically contaminated areas, must provide brief protection (less than 8 hours) from chemical agents, and must show a consistent breakthrough curve for CWAs after an appropriate time (approximately 30 minutes to 8 hours) as identified in an applicable reference, such as the test plan.
Negative control mask.	Must be a full-face protective mask certified for use in industry for chemically contaminated areas that is not a currently fielded U.S. military protective mask, must have a large eye lens, and must consistently provide protection against concentration levels lower than the minimum quantification level of the CWAs for an extended period of time (~ 8 hours to 24 hours) as defined in an applicable reference, such as the test plan.

### 3. REQUIRED TEST CONDITIONS.

SMARTMAN testing requires the handling and use of chemical agents. Chemical agent testing is strictly controlled by Army guidelines (e.g., AR 385-10<sup>2</sup>, DA PAM 385-61<sup>3</sup>, and MIL-STD-882E<sup>4</sup>). Throughout testing, primary emphasis must be on operator and test personnel safety, but the importance of technical quality, completeness of test data, and conformance with specified test and operating procedures cannot be overemphasized.

#### 3.1 Test Planning.

Activation of the test directive constitutes authority to begin planning IAW the project scope of work, guidelines, etc. Test execution is authorized after approval of the test plan and conduct of the test readiness review (TRR) or equivalent, and/or other installation pretest reviews.

##### 3.1.1 Experimental Design.

Design of Experiment (DOE) will be used to develop the test matrix with factors and levels using statistical confidence and power to determine the sample size. However, sample size may be limited by test item availability, cost, or other factors, in that case, other alternatives such as lowering the statistical power, confidence level, or reducing the test conditions must be considered to allow formulation of valid conclusions.

##### 3.1.2 Familiarization.

The test-planning phase includes identifying potential problem areas by reviewing previous records and the results of similar tests. Relevant TOPs, standing operating procedures (SOPs) and other pertinent procedures will be reviewed for applicability, as well as currency, adequacy, and completeness of information. Current methods will be used for execution of test plans; supporting documentation will be updated on an as-needed basis. The development of test plans requires review of the applicable capabilities documents, requirements, specifications and other test guidance, familiarization with preceding development and test phases, study of test criteria, and selection of appropriate samples, methods, sequences, facilities, and test equipment. Data from previous similar tests will be considered in order to avoid duplication and to reduce the scope of further testing.

##### 3.1.3 Documentation.

The project officer ensures availability of all pertinent documentation for planning and review pertaining to the test, including the following: government and manufacturers' publications, requirements documents, capabilities documents, OEP, safety documentation, test directive, record of environmental consideration (REC), operations security (OPSEC) documentation (if applicable), and other documentation, as necessary (e.g., TOPs and SOPs). These documents will contain test criteria, equipment or item specifications, and specific directions about the tests to be performed.



#### 3.1.4 Environmental Considerations.

Compliance with all local, state, and federal regulations is required. Appropriate environmental documentation will be prepared and submitted, and approval will be received before testing begins. All hazardous waste generated by the execution of the test plan will be disposed of IAW federal, state, and local rules and regulations, the installation hazardous waste management plan, and all other applicable installation procedures.

#### 3.1.5 Unique Personnel Requirements.

a. This test requires personnel trained in handling CWAs and simulants. The individuals must also be qualified to operate the analytical, referee, and/or other equipment associated with the SMARTMAN test systems (SOP WDC-ANA-027<sup>5</sup>).

b. Individuals who handle CWAs above the surety threshold level must be enrolled in the Chemical Personnel Reliability Program (CPRP), or other appropriate training program IAW DA PAM 385-61<sup>3</sup>.

#### 3.1.6 Safety.

Applicable safety and surety regulations will be reviewed to ensure compliance of all test procedures. The test project officer and/or project scientist, in consultation with the installation safety office, will prepare a safety procedures and risk management report for inclusion with the test plan.

#### 3.1.7 Surety.

All activities with CWAs and NTAs must comply with surety regulations<sup>3</sup>. In addition, any operation that would not comply with surety regulations will require approval of an exemption.

### 3.2 Preparations for Test.

Test preparations include selecting and readying the test chamber, instruments, samplers, and equipment needed for the test execution, verifying CWA/simulant purity, and preparing the masks to be tested. Preparation may require certain preliminary activities to be specified in the DTP. The project officer will ensure that new equipment training (NET) is provided by the developer whenever necessary.

#### 3.2.1 Masks and Mask Systems.

The masks will be tested in new condition and/or after they are subjected to various types of pretest conditioning. The number of masks chosen to represent each type of pretest conditioning will be divided (equally, insofar as possible) between the CWA or simulant challenges per the test matrix. Preconditioned masks will be cleaned IAW customer and/or manufacturer recommendation before being presented for SMARTMAN testing. **NOTE:** Some level of cleaning would be needed before a warfighter would don a mask that had sand, fuel, etc., on it. The mask also needs to be cleaned so that the mask will seal on the headform and the mask valves will work properly. This does not negate the pretest conditioning.

a. Masks undergoing BFC conditioning will be conditioned before being presented for SMARTMAN testing. The contaminants used will be detailed in the test plan and/or report. Different contaminants may include, but are not limited to, jet propulsion fuel type 8 (JP-8), gasoline, diesel, reactive skin decontamination lotion (RSDL), hydraulic fluid, insect repellent, camouflage cream, and/or other contaminants specified by the requirements document.

b. Any environmental conditioning will be completed before the masks are presented for SMARTMAN testing. The environmental exposure conditioning performed will be detailed in the test plan and/or report. Adverse environmental conditioning may include exposure to combinations of any or all of the following: ozone, temperature shock, high temperature, high humidity, low temperature, low humidity, fungus, salt fog, blowing sand, blowing dust, solar radiation, rain, rough handling, simulated storage (aged), and/or other adverse environmental conditioning specified by the requirements document.

c. Masks may be presented in worn condition for SMARTMAN testing after developmental testing, expected life cycle rotation, etc.

### 3.2.2 SMARTMAN Test System and Instrumentation/Equipment Preparation.

a. The SMARTMAN test system is composed of an environmental chamber housing an agent disseminator, an agent detection system, and a SMARTMAN head form with a breather pump that draws air into the head form. It is recommended that the SMARTMAN chamber be constructed of material that does not absorb chemical vapor, for example, stainless steel. Chamber windows or doors must be constructed of transparent materials that can be replaced periodically. **NOTE:** The medium-sized SMARTMAN head form represents a fiftieth percentile male from the mid-torso to the top of the head in all dimensions IAW the Army Anthropometric Survey Database<sup>6</sup>.

b. The vapor portion of the L/V chemical agent challenge will be created by disseminating liquid agent with a syringe pump disseminator or equivalent using metered infusion of liquid agent onto a heated surface, or by other means to create a true vapor (not an aerosol). Vapor will be formed, entrained in an air stream, and delivered to the chamber. The syringe pump disseminator will be operated IAW manufacturer's instructions, and/or the installation SOP.

c. NRT instruments capable of response times of at least every 2 minutes and the ability to measure chemical concentrations are used for determining the concentrations of the different CWA challenges in the airstream.

d. G-agent (Nerve Agent) Challenges. A MIRAN<sup>®</sup>, or equivalent, with a single-beam infrared spectrometer, will measure the G-agent concentration in the chamber. The spectrometer detector outputs will be digitized, stored, and analyzed in the data acquisition computer. Each instrument will be calibrated IAW procedures in SOPs WDC-ANA-027<sup>5</sup> and WDC-ANA-002<sup>7</sup> (or equivalent calibration procedures) by disseminating a minimum of four calculated concentrations of the agent and recording the voltage output for each point to establish a calibration curve covering the range specified by the project requirements [e.g., concentration range for calibration of 0 to 5000 mg/m<sup>3</sup> for sarin (GB)]. The curve will have a calibration coefficient of 0.95 or better, and each point will be within  $\pm 15$  percent of the expected value. The calibration curve for

each instrument will be QC challenged at a concentration equivalent to the maximum challenge concentration for the given agent as specified in the test plan (e.g., 4000-mg/m<sup>3</sup> for GB). The QC challenge will be performed after calibration, between phases of testing, and at the end of the program. The QC challenge recovery must be within  $\pm 15$  percent of the expected value. The calibration points will be rerun or the instrument will be recalibrated if any calibration points, the coefficient, or the QC challenge fall out of established ranges.

e. H-agent (Blister Agent) Challenges. An Airwaves Sulfur/Phosphorus Analyzer (Air-wave Electronics Ltd, Calgary, Alberta, Canada) or equivalent, which pulls a continuous air stream from the test atmosphere to an FPD, will be set to analyze sulfur and used to measure the H-agent concentration in the chamber. The FPD outputs will be analyzed, digitized, and stored in the data acquisition computer. Before this test program begins, each sulfur analyzer will be calibrated by disseminating a minimum of four calculated concentrations of chemical challenge and recording the voltage output for each point to establish a calibration curve covering the range specified by the project requirements [e.g., concentration range of 0 to 70 mg/m<sup>3</sup> for distilled mustard (HD)] into the Airwaves Electronics sulfur analyzer until the voltage output readings are level. The curve will have a calibration coefficient of 0.95 or better. The instrument calibration curve will be challenged with a QC challenge at a concentration equivalent to the maximum challenge concentration for the given agent, as specified in the test plan (e.g., 50 mg/m<sup>3</sup> for HD). The QC challenge will be performed after calibration, between phases of testing, and at the end of the program. The QC challenge recovery must be within  $\pm 15$  percent of the expected value<sup>5</sup>. The calibration points will be rerun or the instrument will be recalibrated if any calibration points, the coefficient or the QC challenge fall out of established ranges.

f. Persistent Nerve Agent (VX) Challenges. An Airwaves Sulfur/Phosphorus Analyzer or equivalent, which pulls a continuous air stream from the test atmosphere to a FPD, will be set to analyze phosphorus and used to measure the VX chamber concentrations of G-analog (a G-series nerve agent resulting from breakdown products of VX), usually an ethyl form of GB. The FPD outputs will be analyzed, digitized, and stored in the data acquisition computer. Before this test program begins, each phosphorus analyzer will be calibrated by disseminating GB or G-analog vapor using a minimum of four reference concentrations specified by the project requirements (e.g., concentrations ranging from 0.015 to 0.5 mg/m<sup>3</sup>) into the Airwaves Electronics phosphorus analyzer until the voltage output readings are level. The concentrations and voltage output of the detector for each point will be recorded to establish a calibration curve. The curve will have a calibration coefficient of 0.95 or better. The phosphorus analyzer calibration curve will be challenged with a QC challenge (e.g., 0.1 mg/m<sup>3</sup> for VX). The QC challenge will be performed after calibration, between phases of testing, and at the end of the program. The QC challenge recovery must be within  $\pm 15$  percent of expected value. SOP WDC-ANA-027<sup>5</sup> will be consulted for calculations of dissemination concentrations. Because of the difficulties with measuring and sampling the vapor concentration of VX, VX G-analog will be measured in the chamber by converting the VX to the G-analog using silver fluoride (AgF) pads inserted at the distal end of the sampling line. The calibration points will be rerun or the instrument will be recalibrated if any calibration points, the coefficient or the QC challenge fall out of established ranges.

g. Agent vapor breakthrough concentrations will be measured using two MINICAMS<sup>®</sup>, or equivalent instrument, per SMARTMAN test fixture. One instrument will sample from the

nose region, and the other will sample from the eye region. The outputs will be analyzed, digitized, and stored in the data acquisition computer. The MINICAMS<sup>®</sup> uses an FPD detector with a phosphorus filter to detect G-agents and VX, and an FPD with a sulfur filter to detect H-agent. VX is converted to G-analog using AgF pads.

h. Before SMARTMAN testing, the minimum quantification limit (MQL) for each agent/simulant will be established for each instrument. After an acceptable calibration has been completed, a minimum detection limit (MDL) will be established for each analyte by analyzing seven replicate standard injections and one blank. The injections will be at a concentration near the lower end of the calibration range. The MDL will be calculated by multiplying the standard deviation of the seven (minimum required) sample results by the Student's *t*-test value at the 95-percent confidence interval. The MQL will be defined as 3 to 5 times the MDL. Based on this MQL, the time to reach the target cumulative concentration ( $\text{mg}\cdot\text{min}/\text{m}^3$ ) multiplied by time (CT) specified in the requirements document will be calculated. Similarly, a minimum measurable cumulative CT for 16 and 24 hours will be calculated. Concentrations and/or CT will be reported, but the CT may or may not be required depending upon the test program.

i. The MINICAMS<sup>®</sup> flow rate, vapor collection times, MQL, and total cycle time for each agent will be recorded and presented in a table (see Table 1). The systems will begin monitoring for breakthrough in the mask when agent is disseminated.

j. Check shots for determining precision and accuracy of the recovery procedure for each agent or simulant used will be performed IAW procedures found in SOP WDC-QAC-003R<sup>8</sup>.

(1) The check shot sample injections will be made at the eye and nose ports of the SMARTMAN head form to confirm sample recovery at acceptable levels.

Table 1. EXAMPLE OF MINICAMS<sup>®</sup> (A MINIATURE, AUTOMATIC, CONTINUOUS AIR-MONITORING SYSTEM) MINIMUM QUANTIFICATION LIMITS (MQLS) AND TEST PARAMETERS FOR AGENT VAPOR BREAKTHROUGH MEASUREMENTS.

Agent <sup>a</sup>	MQL ( $\text{mg}/\text{m}^3$ )	Flow ( $\text{mL}/\text{min}$ )	Sample Time (min)	Cycle Time (min)
GB	$2.5 \times 10^{-4}$	200	1	3
GD	$2.5 \times 10^{-4}$	200	1	3
HD	$5.0 \times 10^{-3}$	100	2	5
VX	$1.25 \times 10^{-5}$	500	8	10

<sup>a</sup>GB – sarin; GD – soman; HD – distilled mustard; VX – persistent nerve agent.

(2) Eight replicates of a low-range standard and eight replicates of a mid-range standard will be injected into the eye and nose ports. These injections will be analyzed with the calibrated MINICAMS<sup>®</sup>. The percent recovery will be calculated and used to establish the precision and accuracy of injections for comparison with future injections [percent recovered = (recovered value/expected value) × 100]. The amounts of standard injected and recovered, percent recovery, and the precision and accuracy of the injections will be recorded. **NOTE:** Eight replicates are considered sufficient for the Student's *t*-test statistical analysis.

k. Positive and negative control masks will be used to check the SMARTMAN fixture. Controls will be set up before the trials for record begin. Commercial off-the-shelf (COTS) masks certified as chemical environment protective masks by the National Institute for Occupational Safety and Health [(NIOSH), Centers for Disease Control and Prevention, Atlanta, Georgia] will be used for the control masks. The breakthrough times and concentrations will be recorded for reference. The average times until the MQL for the CWAs/simulants is reached will be calculated and recorded for reference. The COTS control masks will also be used, if necessary, for failure analysis.

(1) Positive Control Mask. The COTS mask selected for use as a positive control must provide brief protection from chemical agents and show a consistent breakthrough curve for CWAs after a short time. An emergency escape hood used in industry for chemically contaminated areas is a good candidate.

(2) Negative Control Mask. The COTS mask selected for use as a negative control must not be a currently fielded U.S. military protective mask, must have a large eye lens, and must provide a level of protection lower than the MQL for an extended period of time. A full-face protective mask used in industry for chemically contaminated areas is a good candidate.

### 3.3 Quality Assurance (QA) and Quality Control (QC).

Controls and limitations applicable to a specific test preparation or subtest are presented in Paragraph 4 as part of the procedure to which they apply.

a. A QA plan must be prepared for each test program to ensure that variables are controlled and that appropriate records are kept throughout the duration of testing. Test variables include: purity and stability of agents and simulants used, humidity and temperature, breathing rate, calibration and maintenance of instrumentation and disseminators, accuracy and precision of the laboratory analysis, and quality and uniformity of all test samples.

b. The condition of the test item at the time of testing is an important test variable. As part of SMARTMAN testing, receipt inspection of the test items will be conducted IAW TOP 8-2-500<sup>9</sup> before SMARTMAN trials begin. Inspection data, certificates of compliance, or similar documentation, will be reviewed to ensure that exterior surfaces, finishes, and packaging meet specifications. Generally, the item will be tested in as-received condition, which will simulate likely mask condition as closely as possible when issued to warfighters in the theater of operations. SMARTMAN testing may be required periodically throughout the equipment life cycle if the effects of normal wear or storage conditions are a major factor in survivability.

c. Testing must always be conducted IAW approved test documentation, such as technical manuals, field manuals, equipment operating instructions, SOPs, the approved test directive, OEP, TEMP, and the test plan. Deviations from approved test documentation will be documented and approved by the appropriate authority.

#### 4. TEST PROCEDURES.

##### 4.1 Test Methods and Procedures Overview.

###### 4.1.1 Test Method Outline.

a. Receipt inspection will be conducted on the system under test to document as-received material conditions. Receipt inspection may include functional performance tests to establish baseline performance parameters (if applicable). Paragraph 4.2 describes the details for this step of the test method.

b. The agents/simulants will be prepared for application as described in Paragraph 4.3.

c. After pretrial preparations are completed for the SMARTMAN test system and instrumentation/equipment (Paragraph 3.2.2), test execution will follow the steps in Paragraph 4.4.

(1) Masks will be prepared for testing, to include pretrial inspection, identification, and documentation (Paragraph 4.4.1.a).

(2) A qualitative leak check will be conducted on each mask (Paragraphs 4.4.1.b through 4.4.1.e).

(3) Test chamber operation will be initiated and environmental conditions for the test will be stabilized. Environmental conditions will be monitored and recorded (Paragraph 4.4.1.f).

(4) Liquid agents/simulants will be applied to the item under test, and liquid droplet application locations, amounts, etc. will be recorded. Agent/simulant vapor will be generated, monitored, and sampled. The details of this step are described in Paragraphs 4.4.1.g through 4.4.1.k.

(5) Vapor sampling, monitoring, and sample analysis will be conducted as described in Paragraphs 4.4.1.l through 4.4.1.n.

d. Posttest inspection (optional) will be performed as described in Paragraph 4.5.

e. Data analysis will be performed IAW Paragraph 6.2.

###### 4.1.2 Significance and Use.

a. The sample data collected from this test allow a determination of vapor hazards to protected personnel from a CWA-contaminated environment.

b. The data collected from preconditioned masks allow a determination of the amount of physical and/or functional degradation of the system that result from various adverse conditions, exposure to contaminants, aging of the item, etc.

#### 4.1.3 Interferences.

There are no expected interferences when the test method is conducted under laboratory-controlled conditions.

#### 4.1.4 Apparatus.

The term apparatus will apply to the test fixture in which a test method may be conducted as well as to the equipment used in conducting testing, sampling, and analytical instrumentation.

#### 4.1.5 Hazards.

a. Identified safety hazards are those associated with testing using toxic chemical surety materials, simulants, and decontaminant chemicals that are hazardous in and of themselves (e.g., chlorine, hydrogen peroxide, etc.). Chemical safety guidelines are in DA PAM 385-61<sup>3</sup>.

b. A test plan must be developed with a safety section identifying and addressing all safety concerns for each test conducted using these methods IAW AR 385-10<sup>2</sup>. The safety section of the test plan will be coordinated with the installation's safety office.

#### 4.1.6 Calibrations and Standards.

a. Calibration of the primary equipment and instruments used in SMARTMAN testing will be performed during test preparations. Specific information and procedure summaries are given in Paragraph 3.2.2. All equipment and instruments should be on a preventative maintenance and/or calibration program (where applicable), and calibration must be current at the time of testing.

b. Certified standards may be purchased, but must be used before the expiration date. The chemical supplier must provide a certificate/guarantee of purity, and the supplier name, manufacturer name, certificate number, purity, and dates (manufacture and expiration) must be provided in the final report.

c. General chemical analytical calibration guidelines are found in SOP WDC-ANA-034<sup>10</sup>. These guidelines can be used for most chemical analytical equipment (e.g., GCs, LCs, etc.). Before analytical calibration, a sample sequence will be created that includes the following:

(1) A blank sample to evaluate analytical method interferences.

(2) Calibration standard samples (ranked low to high or high to low by concentration) with at least five standards. Calibration standards may either be prepared or purchased:

(a) Preparations for standards are described in SOP DP-0000-M-073<sup>11</sup>.

(b) Certified standards may be purchased, but must be used within the expiration date. For chemicals purchased from a chemical supplier, the purity must be certified and/or guaranteed, and the information supplied on the certificate will be included in the final report.

(3) A blank sample to evaluate carryover.

(4) A QC sample to validate the calibration curve, at least one sample per detector (if multiple detectors are installed on the same instrument) including control samples.

(5) Another blank sample.

d. The same method will be used to analyze all samples.

e. Using the instrument software (where available), the calibration curve will be built from lowest to highest concentration.

f. Plot information will be evaluated as follows:

(1) Curve fit type (linear, quadratic, etc.) will be selected.

(2) Point weighting method (equal, inverse, etc.) will be selected.

(3) If correlation value ( $R^2$ ) is greater than 0.95 (if not otherwise specified) for all instruments except breakthrough MINICAMS<sup>®</sup> ( $R^2=0.99$ ), then analysis will proceed.

(4) If  $R^2$  is less than 0.95 (if not otherwise specified) for all instruments except breakthrough MINICAMS<sup>®</sup> ( $R^2=0.99$ ), then data points may be removed or rerun and the calibration curve recalculated. No more than one data point may be removed without calibrations being rerun. If data points are removed and/or calibration curve recalculated, the reason(s) will be noted in the laboratory log book.

(5) If correlation still fails, each data point will be evaluated to determine any errors.

(6) Method adjustments will be made and the calibration repeated.

(7) If correlation fails, troubleshooting assistance will be requested from within the organization.

g. If all criteria are met, the QC sample will be loaded and processed against the calibration curve.

h. The measured values for the QC sample must be within  $\pm 15$  percent of the expected value.

(1) If the QC measured value meets the criteria, then the test method will proceed.

(2) If the QC measured value does not meet the criteria, then a second QC sample will be run.



(3) If the second QC measured value meets the criteria, then the test method will proceed.

(4) If the second QC measured value does not meet the criteria, then corrective actions and recalibration will be performed to the instrument.

i. After any maintenance is performed on the instrument, two QC samples must show an analyzed value within  $\pm 15$  percent of the expected value or corrective actions and recalibration must be performed.

#### 4.2 Receipt Inspection.

##### 4.2.1 Receipt Inspection Method.

a. This subtest will be conducted IAW TOP 08-2-500<sup>9</sup>.

b. Receipt inspection data will be entered into the individual data tracking system used at the installation. Test item control numbers (TICNs), to be used throughout testing, will be assigned by the test item control officer. Preconditioned/worn masks presented for additional testing may already have a TICN assigned for use throughout all testing stages; therefore, it is possible that the TICN will be assigned before the masks arrive at the installation performing the SMARTMAN testing. The serial number (SN), TICN, and configuration for each mask will be recorded.

c. The initial receipt inspection will be performed immediately after the masks are received.

(1) Test items and external packaging will be inspected for damage. In addition, the test items will be inspected and compared with the original order and shipping information to ensure proper quality and quantities.

(2) Masks and mask components (such as filter cartridge, nose cup, neck dam, etc.) will be inspected for surface degradation, damage, and faulty workmanship, including tears, rips, cuts, abrasions, punctures, color variation, blemishes, splits, cracks, excess flash, component separation, foreign matter, and contamination such as dirt, grease, or oil.

(3) Receipt inspection will include functional performance tests, if applicable, to establish baseline performance parameters (e.g., blower is operational, etc.) of any mechanical/electronic components of a mask system. To ensure the mask is functioning properly it will be tested with a TDA-99M dual-purpose field mask leakage tester or the JSMLT (Joint Service Mask Leak Tester) (Air Techniques International, Baltimore, Maryland).

(4) Photographs (with metric scale) will be taken of any damage found.

(5) Inspectors will make note of the pretest condition of any area(s) specified (e.g., eye lens condition) for comparison and use in the optional posttest inspection, if required.

d. Receipt inspection will be performed on all masks presented for SMARTMAN testing, including the conditioned/worn masks received for additional testing.

e. Individual canister/filter containers will be removed from their hermetically sealed outer containers only immediately before the items are to be used in the specific subtests.

f. Any test item or test item component with an obvious defect that will cause a protection failure or a safety hazard to a wearer will be removed from further testing and replaced if possible.

#### 4.2.2 Receipt Inspection Data Required.

- a. SN, TICN, and configuration of each test item.
- b. Any abnormalities or problems with the test materials.
- c. Photographs (with metric scale) taken of any abnormalities or damage.

#### 4.3 Chemical Purity Analysis and Preparation.

a. Unless otherwise stated, the required chemical purity of CWAs and simulants used in SMARTMAN testing must be at least 90 percent. The required chemical purity for any TICs, NTAs, etc., will be determined by the requirements document.

b. Vapor challenges do not require a thickener. Liquid challenges may require a thickener if specified in the test plan. The agents to be used during SMARTMAN testing are as follows:

(1) Neat VX with purity greater than 90 percent is required, unless a weapons-grade mixture is desired (SOP WDC-ANA-031<sup>12</sup>).

(2) Neat G-agent with purity greater than 90 percent is required, unless a weapons-grade mixture is desired (SOP WDC-ANA-031<sup>12</sup>). If specified in the test plan, G-agent may be thickened with Rohm and Haas Acryloid™ K125 (Philadelphia, Pennsylvania) poly(methyl methacrylate) (SOP WDC-ANA-012<sup>13</sup>).

(3) Neat HD with a purity greater than 90 percent is required, unless a weapons-grade mixture is desired (SOP WDC-ANA-031<sup>12</sup>).

(4) Other approved contaminants (e.g., NTAs, TICs, TIMs) as specified in the TEMP.

c. Simulants to be used are specified in the test plan. Simulants may be prepared with a suitable dye or thickener, if needed.

##### 4.3.1 Chemical Purity Analysis Method.

a. For chemicals of unknown purity (e.g., weapons grade), or those needing further verification, the following procedures will be performed before testing begins:

(1) Purity analysis will be performed IAW the SOP for Chemical Purity Analysis, SOP WDC-ANA-031<sup>12</sup>.

(2) Purity analysis results will be included in the final report.

b. For chemicals purchased from a chemical supplier, the purity must be certified and/or guaranteed, and the information supplied on the certificate will be included in the final report.

c. If agent is used over a long period of time (6 months), the purity should be re-verified during testing IAW good laboratory practices and the SOP<sup>12</sup>.

#### 4.3.2 Chemical Purity Analysis Data Required.

a. Source and/or supplier.

b. Pertinent dates (e.g., date of purchase, date opened, date analyzed, and expiration date, if applicable).

c. Lot number, Chemical Abstracts Service (CAS) number, name of chemical.

d. Purity analysis results or supplier-certified/guaranteed purity of that lot.

#### 4.4 SMARTMAN Test Execution.

##### 4.4.1 SMARTMAN Test Execution Method.

General procedures for the SMARTMAN test fixture setup and operation, mask sealing and leak check procedures, and analytical instrument operation are in SOP WDC-ANA-027<sup>5</sup>.

a. Before each challenge, the mask configuration, SN, TICN and/or other identification will be recorded. The unit pack will be opened IAW user instructions, and the mask will be visually inspected for observed problem areas, compatibility issues, damage, and/or surface degradation. Masks should be leakage performance tested before agent resistance testing on the SMARTMAN fixture.

(1) The mask will not be cleared for testing until readings on the leak tester are at least the minimum qualitative fit factor (FF) value. The minimum qualitative FF value will be the test assets' threshold FF value required by the mask's capability document or the performance specification for the mask, or minimum FF value will be 50,000, whichever is lower.

(2) The approximate FF will be calculated by dividing the oil aerosol concentration on the inside of the mask by the oil aerosol concentration on the outside of the mask. The leak tester first generates the oil aerosol from a dispenser wand and then measures the oil aerosol concentration inside the mask through a sample line that returns back to the instrument.

b. The SMARTMAN test system is composed of an environmental chamber housing an agent disseminator, an agent detection system, and a SMARTMAN head form with a breather pump that draws air into the head form. **NOTE:** The medium-sized SMARTMAN head form

represents a fiftieth percentile male from the mid-torso to the top of the head in all dimensions IAW the Army Anthropometric Survey Database<sup>6</sup>.

c. Each mask will be placed on the test head form in the exposure chamber IAW user donning instructions. All masks will have at least one or a combination of the nose cup, face, or neck dam sealing features.

d. A pre-trial qualitative leak check will be performed on each mask using a TDA-99M dual-purpose field mask leakage tester or JSMLT, while the mask is in operational mode, i.e., with breathing pump operational, blowers and supplied air if configured. The results will be recorded as a pass/fail when the readings on the instrument stay below 0.001 ppb throughout the leak check. This leak check is performed with the leak tester modified to sample from the SMARTMAN sample ports and the tester set in leak check mode.

(1) For masks that require a complete seal on the nose cup for proper operation (e.g., flight masks), the nose cup (oronasal area) will be isolated from the rest of the mask and the hood cavity with the use of a face gasket (constructed and supplied by ECBC) and Tacky Tape<sup>®</sup> (Schnee-Morehead, Inc., Irving, Texas), or equivalent laboratory sealant. A leak check using the TDA-99M tester or JSMLT will be performed to test the nose cup seal. A nose cup seal check may be accomplished by introducing oil aerosol from the TDA-99M into the eye area via the eye sampling line or the forehead port and measuring the oil aerosol concentration inside the nose cup via one of the nose sampling lines. This is done with the mask in a stagnant state, without the breather pump or blowers in operation. The nose cup seal is verified with readings on the leak tester less than 0.001 ppb.

(2) After the nose cup seal is verified, a qualitative leak test using the modified TDA-99M tester or JSMLT will be conducted to ensure that the mask is adequately sealed to the head form, the outlet valve is functioning properly, and the mask has no leaks. This test will be conducted with the breathing pump running and all other mask components functioning. The leak tester probe will be passed over all the mask surfaces. If a leak is detected, the mask or valves will be adjusted until the mask passes the leak test, if possible. Measurements will be made in the eye- and nose-cup regions.

(3) Face seal masks must have the SMARTMAN face seal bladder expanded to the recommended pressure of 4- to 6-psi before performing a leak check.

(4) Neck dam masks need to have the neck dam flattened, without any rolls or folds, against the neck portion of the SMARTMAN headform before performing a leak check.

(5) If a mask is unable to meet the qualitative leak test readings required, the customer program office will be contacted for further guidance.

e. The test will be conducted at a flow rate specified in the requirements documents/test plan and with a simulated breather flow rate within the range of human breathing rates. If not otherwise specified, the simulated breather flow rate will be around the average human breathing rate of  $33 \pm 1$  cycles/min. The head form breather pump, which is adjustable, and has a standard volume of 1.5 L/breath, will be powered on for the full duration of the test. The mask blower (if

applicable) will run for the time specified in the test plan, which can be part or all of the test duration. Temperature and RH will be controlled at the levels specified in the requirements documents or test plan and recorded. The mask will not be pre-equilibrated unless otherwise specified.

f. After the mask passes leak checking and the chamber is at operational conditions, then the liquid agent/simulant will be applied to the mask for the liquid portion of the L/V test and agent/simulant vapor will be generated.

g. The vapor portion of the L/V chemical agent challenge will be created by disseminating liquid agent with a syringe pump disseminator or equivalent using metered infusion of liquid agent onto a heated surface, or other means to create a true vapor (not an aerosol). Vapor will be formed, entrained in an air stream, and delivered to the chamber. Values recorded below the MQL (see Table 1) will be set to 0 when calculating the chamber CT and/or concentration challenge. The minimum chamber concentration detection limit for the agents or simulants will be stated in the report.

h. For CWA/simulant vapor testing, the challenge concentration will start at  $0 \text{ mg/m}^3$  and increase to a high concentration that is within the threshold and optimal high-concentration ranges stated in the requirements document. The high-challenge concentration will be maintained for a specified amount of time. The challenge will then be decreased to low concentrations and be maintained for specified times, before being allowed to naturally decay for the remainder of the trial. If required by the test program, the calculation of an overall challenge for the cumulative CT in  $\text{mg}\cdot\text{min/m}^3$  within the range specified in the requirements document is obtained by multiplying the concentration achieved for the duration of the trial time. The actual challenge concentration, elapsed time, and cumulative CT (if applicable) will be recorded.

i. For the liquid portion of L/V testing, the mask system, including the hoses, will be spiked with 10- or 20- $\mu\text{L}$  drops of liquid agent applied at a standard contamination density of  $10 \text{ g/m}^2$  (unless otherwise specified in the requirements document) to achieve the desired challenge concentration. A table summarizing the liquid droplet application locations, and the droplet dissemination pattern diagrams, preferably using photograph(s) of the test item with locations indicated, will be included in the report.

j. The vapor challenge concentration from the applied liquid will be measured and allowed to decay for the remainder of the minimum trial time or until the desired cumulative CT (if used) is achieved. The maximum trial time set by the requirements document or test plan will not be exceeded, even if the target cumulative CT (if applicable) is not achieved during that time. The actual challenge concentration, elapsed time, and cumulative CT (if applicable) will be recorded.

k. In-mask agent vapor concentration above MQL will be measured for the duration of each trial, through the eye and nose ports of the SMARTMAN test fixture, and recorded. In-mask agent concentration levels above criterion will be noted and recorded.

l. Any other pertinent observations or remarks will be recorded. Posttest inspection, if required by the customer and included in the test plan, or if necessary, failure analysis will be conducted and recorded. Posttest inspection or failure analysis may include the following:

(1) Posttest leak check involving a close inspection of the mask can be completed before it is removed from the head form if the seal is in question. Areas inspected will include, but are not limited to, the peripheral seal, outlet valve, drink tube, or any other pertinent parts that may have come loose.

(2) Close inspection of specified areas of the mask for damage from agent. These could include eye lens area, hoses, material interface connections, etc.

(3) Inspection of potential fixture connection problems (e.g., loose sample lines, face bladder).

(1) Photographs of any problem areas can be taken to record pertinent observations.

m. Charts comparing in-mask concentration will be prepared with time and the breakthrough time for the eye and nose regions of the mask. Other charts and tables as mentioned in Paragraphs 6.2.2, 6.2.4, and 6.2.5 will also be prepared for data comparison and analysis.

#### 4.4.2 SMARTMAN Test Execution Data Required.

a. Mask SN.

b. TICN or other identification.

c. Any pretest conditioning and configuration of the mask.

d. Concentration of vapor in the exposure chamber for the duration of the test.

e. Amount of liquid agent or simulant deposited on the test items (if applicable).

f. Results of TDA-99 (or equivalent instrument) leak tests and FF tests.

g. Charts comparing in-mask concentration above MQL with the elapsed trial time and the time until any vapor concentration above test criterion occurs for both the eye and nose regions for the duration of the trial.

h. Breathing rate of breather pump and flow rate of system blower (if applicable). The mask blower run time (if applicable) will be noted in the test plan and report.

i. Environmental Conditions.

(1) Required: chamber temperature (°C) and RH (percent).

(2) Optional: differential pressure ( $\Delta P$ ) between the fume hood and the chamber in inches water gauge (iwg), and the  $\Delta P$  between the respirator and the chamber (iwg).

- j. CWA, simulant, NTA, or TIC/TIM challenge concentration ( $\text{mg}/\text{m}^3$ ).
- k. Chemical challenge CT ( $\text{mg}\cdot\text{min}/\text{m}^3$ ), if required in the test plan.
- l. Chemical sample masses (ng) and CTs ( $\text{mg}\cdot\text{min}/\text{m}^3$ ) from the nose port and the eye port.
- m. The MINICAMS<sup>®</sup> (or equivalent) calibrations, parameter settings, MQL, MDL, sample flow rate (L/min), the sample flow duration (min), CWA results, and the cycle duration (min).
- n. The MIRAN<sup>®</sup> (or equivalent) calibrations, parameter settings, MQL, MDL, sample flow rate (L/min), the sample flow duration (min), CWA results, and the cycle duration (min).
- o. Phosphorus and/or sulfur analyzer data.
- p. Failure analysis (if applicable).
- q. Any other pertinent observations or remarks (for example, any observed problem areas, compatibility problems, or damages).

#### 4.5 Posttest Inspection (Optional).

##### 4.5.1 Posttest Inspection Method.

- a. This subtest will be conducted IAW customer request.
- b. The outer surface of the mask, especially areas such as the eye lens, will be visually inspected following agent/simulant SMARTMAN testing, and any physical degradation will be noted. Any abnormalities or damage will be described and noted, and photographs will be taken that show the TICN for the test item.

##### 4.5.2 Post-test Inspection Data Required.

- a. TICN, SN, or other identification of each test item.
- b. Any posttest observations of abnormalities or problems with the test materials.
- c. Photographs taken (with metric scale) of any posttest abnormalities or damage.

#### 5. DATA REQUIRED.

The data required are listed in Paragraph 4 under each subtest (Paragraphs 4.2.2, 4.3.2, 4.4.2 and 4.5.2).

## 6. PRESENTATION OF DATA.

### 6.1 Plans and Reports.

Plans and reports will be prepared IAW with DA PAM 73-1<sup>14</sup> and U.S. Army Test and Evaluation Command (ATEC) PAM 73-1<sup>15</sup>. Test plans must be approved before the start of testing. During test planning, TOPs, international TOPs (ITOPs), or multinational TOPs (MTOPs) must be used to the maximum extent possible. Unclassified plans/reports/data will be uploaded to the Versatile Information Systems Integrated Online Nationwide (VISION) Digital Library System (VDLS).

### 6.2 Data Analysis/Procedures.

#### 6.2.1 Calculations.

##### 6.2.1.1 In-Mask Vapor Concentration Calculations.

Data analysts will perform the following calculation procedures for the nose- and eye-port samples of in-mask vapor concentrations above MQL as separate sets of measurements:

- a. Divide the mass recovered (ng) by the flow rate (L/min) and the sample flow duration (min), and then divide the resulting quotient by  $(\text{m}^3 \cdot \text{ng})/(\text{L} \cdot \text{mg})$  to convert to the concentration for the sample period.
- b. If CT is required in the test plan or program, multiply the concentration by the chromatographic cycle duration (min) to get the CT ( $\text{mg} \cdot \text{min}/\text{m}^3$ ) for the sample period. Sum the CT values for each sample period over the duration of the trial to determine the cumulative CT.

##### 6.2.1.2 Challenge Concentrations.

Data analysts will perform the following challenge concentration calculation procedures:

- a. Compute the average of the challenge concentration measurements ( $\text{mg}/\text{m}^3$ ) for each sampling interval for the duration of the trial.
- b. If CT is required in the test plan or program, multiply the sampling interval average concentration values ( $\text{mg}/\text{m}^3$ ) by the sampling interval (min) to get the challenge CT ( $\text{mg} \cdot \text{min}/\text{m}^3$ ) for each sample period. Sum the CT values for each sample period over the duration of the trial to determine the cumulative challenge CT.

#### 6.2.2 Tables.

- a. The concentrations in the chamber and in-mask above MQL will be reported.
- b. If CT is required by the test program, The cumulative CT values ( $\text{mg} \cdot \text{min}/\text{m}^3$ ) will be tabulated for the nose and eye ports and challenge concentration samples. All cumulative breakthrough CT values must be below the required levels specified in the requirements document for the test criteria stated in the requirements document to be met. Any mask with a cumulative



breakthrough CT value above the criterion level for that CWA will be examined to determine the source of penetration.

c. Example tables, which can be used or modified for data reporting, are in Appendix A, Tables A1 and A.2. Contents in the example tables are for example purposes only.

#### 6.2.3 Photographs.

a. Photographs of any abnormalities or damages will be included in the report and/or the data package supplied to the customer. Each photograph will have proper item identification included in the caption or filename for ease of reference to the provided narrative, report, and/or laboratory records.

b. Photographs of the test item are appropriate for use as a base layer to show the liquid agent dissemination pattern on the mask(s) being tested. An example is given in Appendix A, Figure A.1. Contents in the example figures are for example purposes only.

#### 6.2.4 Graphs.

a. The following data will be plotted on graphs:

(1) The concentration as a function of elapsed time (min) for the samples taken from the nose and eye ports.

(2) If required, the cumulative CT as a function of elapsed time (min) for the samples taken from the nose and eye ports.

(3) The challenge concentration as a function of elapsed time (min).

(4) If required, the cumulative challenge CT as a function of elapsed time (min).

(5) The environmental conditions (temperature and humidity) over time.

b. Example graphs from two trials, one trial using a GB challenge and the other trial using an HD challenge, are included in Appendix A, Figures A.2 through A.17. Contents in the example figures are for example purposes only.

#### 6.2.5 Comparison of Data.

The data will be compiled for analysis. Physical characteristics and limiting factors of tested masks will be evaluated for use in a risk reduction effort for entering developmental/acquisition testing. For example, physical characteristics and limiting factors relating to the test specimens include mask size and possibly any conditions, such as how well a mask facepiece (oronasal area) sealed onto the head form, respiration anomalies peculiar to one specimen or to the population, or other observations that demonstrate weakness in the entire mask system. Such evaluations and/or comparisons will be correlated in relation to observed CT values and their differentials. The data or representations therein can be recorded for display on any suitable engi-

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neering risk assessment tool such as a risk cube, tabular range summary in order of severity, or matrix table. Charts may be used where appropriate or convenient.

## APPENDIX A. EXAMPLE TABLES, PHOTOGRAPHS, AND GRAPHS FOR DATA PRESENTATION

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APPENDIX A. EXAMPLE TABLES, PHOTOGRAPHS, AND GRAPHS FOR DATA  
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Table A.1. EXAMPLE OF SARIN VAPOR (GBV) SIMULANT AGENT RESISTANCE TEST MANIKIN (SMARTMAN) TEST INFORMATION.

Mask Tracking Number	Trial Number	Conditioning	Size	SMARTMAN Test Chamber	MINICAMS <sup>a</sup> MDL <sup>b</sup> (mg/m <sup>3</sup> )	Chamber MDL (mg/m <sup>3</sup> )
TBXQ-23 <sup>c</sup>	TBXQGN023	New	X-Large	1	0.00025	100
TBXQ-05	TBXQGN005	New	Large	2	0.00025	100
TBXQ-17	TBXQGJ017	Diesel; jet propulsion fuel, type 8 (JP-8); gasoline	Medium	3	0.00025	100
TBXQ-03	TBXQGJ003	Diesel; jet propulsion fuel, type 8 (JP-8); gasoline	Large	4	0.00025	100
TBXQ-10	TBXQGR010	Reactive Skin Decontamination Lotion (RSDL)	Large	2	0.00025	100
		Reactive Skin Decontamination Lotion (RSDL)	Medium		0.00025	100
		Hydraulic fluid			0.00025	100
		Hydraulic fluid			0.00025	100
		Insect repellent			0.00025	100
		Insect repellent			0.00025	100
		Salt fog			0.00025	100
		High temperature, temperature shock, humidity, solar radiation			0.00025	100
		Worn			0.00025	100
		Worn			0.00025	100
		Ozone, rain, blowing dust			0.00025	100
		Ozone, rain, blowing sand, blowing dust			0.00025	100

<sup>a</sup>A miniature, automatic, continuous air-monitoring system.

<sup>b</sup>Minimum detection limit.

Table A.2. EXAMPLE OF SARIN VAPOR (GBV) SIMULANT AGENT RESISTANCE TEST MANIKIN (SMARTMAN) TEST RESULTS.

Trial Number	Trial Start Date	Cumulative Challenge CT <sup>a</sup> (mg·min/m <sup>3</sup> )	16-Hour Cumulative Eye CT (mg·min/m <sup>3</sup> )	16-Hour Cumulative Nose CT (mg·min/m <sup>3</sup> )	24-Hour Cumulative Eye CT (mg·min/m <sup>3</sup> )	24-Hour Cumulative Nose CT (mg·min/m <sup>3</sup> )	Trial Comments <sup>b</sup>
TBXQGN023 <sup>c</sup>	19 December 2012	20143	0.06	0.09	0.20	0.14	None
TBXQGJ003	20 December 2012	20150	0.05	0.07	0.18	0.13	(1)

<sup>a</sup>Concentration multiplied by time.

<sup>b</sup>See Table B.x for text of numbered comments. (TOP users: Notations in this column are for example only. Comments would be listed by number in the comment table, which is referred to as Table B.x and not included for these example tables.)

**NOTE:** The MINICAMS<sup>®</sup> (a miniature, automatic, continuous air-monitoring system) detection limit for each sample was 0.000025 mg/m<sup>3</sup> for sarin (GB). If an individual sample value was at or below 0.000025 mg/m<sup>3</sup>, it was reported as zero. If an individual sample value was 0.00006 mg/m<sup>3</sup> or above, that value was added to the cumulative CT calculation.

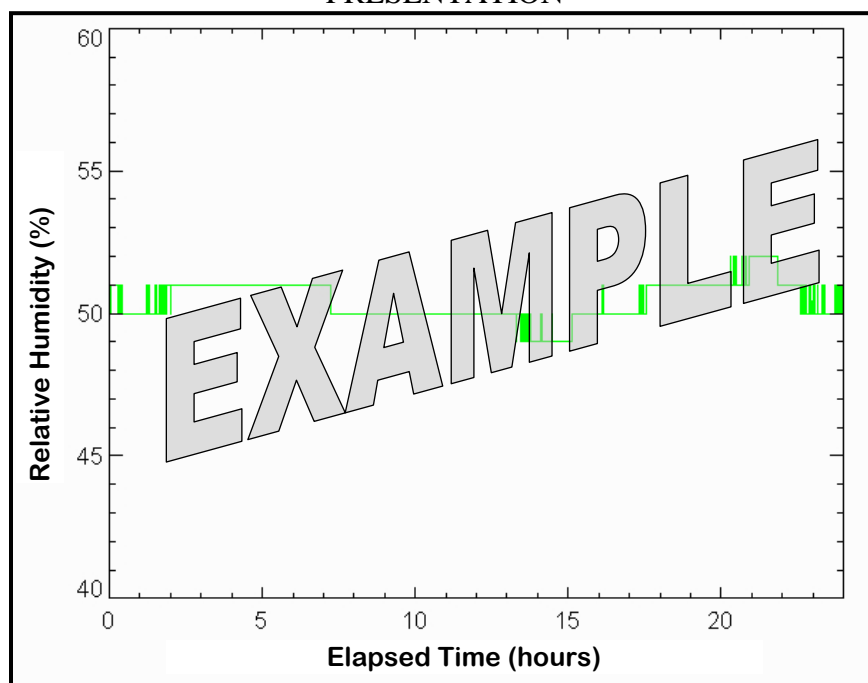
APPENDIX A. EXAMPLE TABLES, PHOTOGRAPHS, AND GRAPHS FOR DATA  
PRESENTATION



**NOTE:** This mask is a face seal mask. The hood was not challenged with agent.

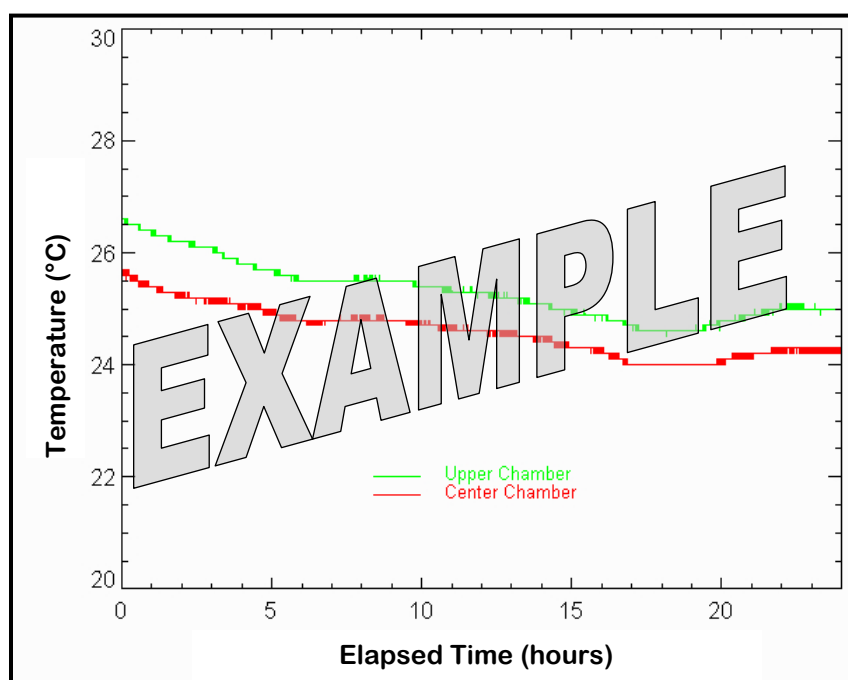
Figure A.1. Example of distilled mustard (HD) droplet contamination pattern illustration using a test item photograph for the base image.

APPENDIX A. EXAMPLE TABLES, PHOTOGRAPHS, AND GRAPHS FOR DATA PRESENTATION



**NOTE:** Mask treated with insect repellent/camouflage cream and contaminated with sarin (GB).

Figure A.2. Example Trial A chamber relative humidity.

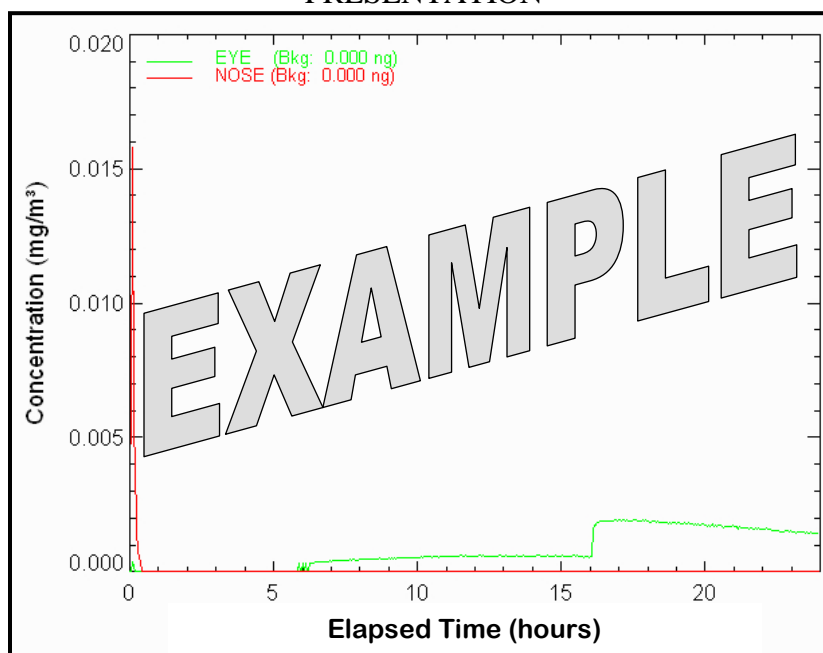


**NOTE:** Mask treated with insect repellent/camouflage cream and contaminated with sarin (GB).

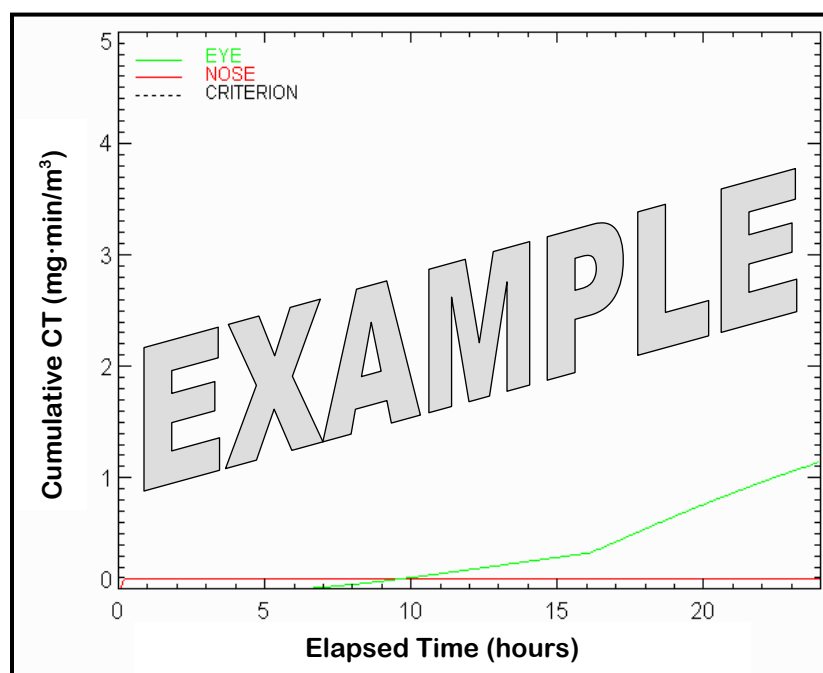
Figure A.3. Example Trial A chamber temperature.



APPENDIX A. EXAMPLE TABLES, PHOTOGRAPHS, AND GRAPHS FOR DATA  
PRESENTATION

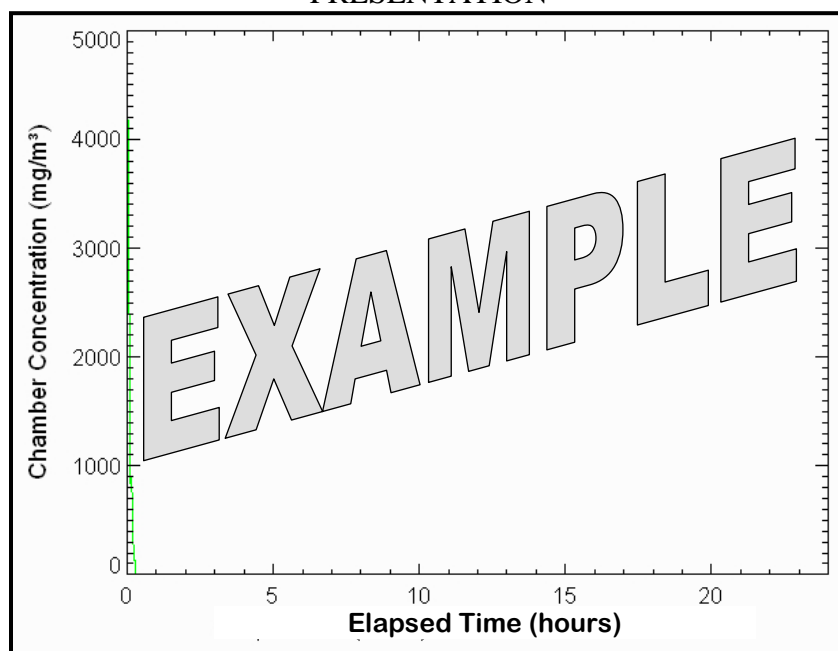


**NOTE:** Mask treated with insect repellent/camouflage cream and contaminated with sarin (GB).  
Figure A.4. Example Trial A mask breakthrough 24-hour challenge sarin (GB) concentration.



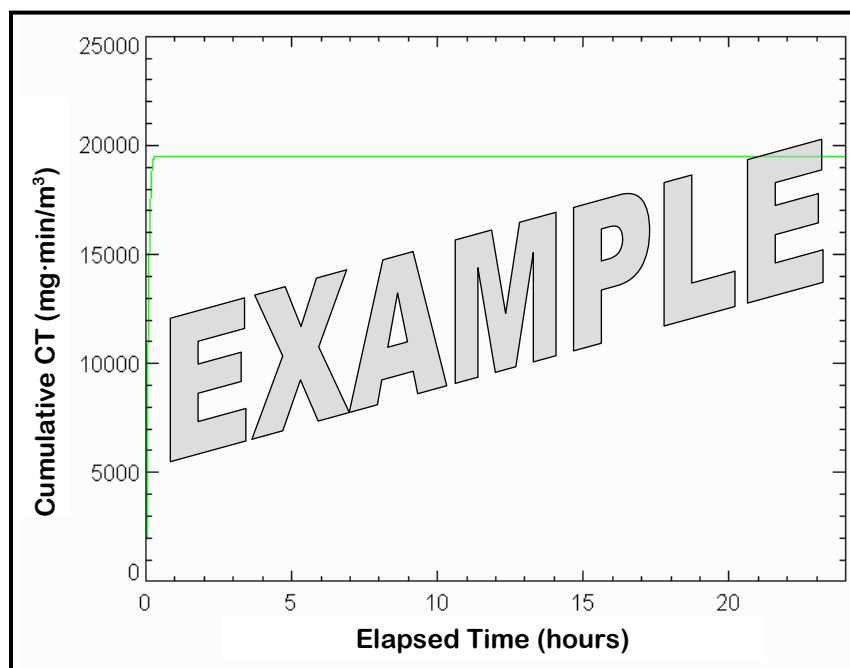
**NOTE:** Mask treated with insect repellent/camouflage cream and contaminated with sarin (GB).  
Figure A.5. Example Trial A mask breakthrough 24-hour challenge sarin (GB)  
cumulative concentration  $\times$  time (CT).

APPENDIX A. EXAMPLE TABLES, PHOTOGRAPHS, AND GRAPHS FOR DATA PRESENTATION



**NOTE:** Mask treated with insect repellent/camouflage cream and contaminated with sarin (GB).

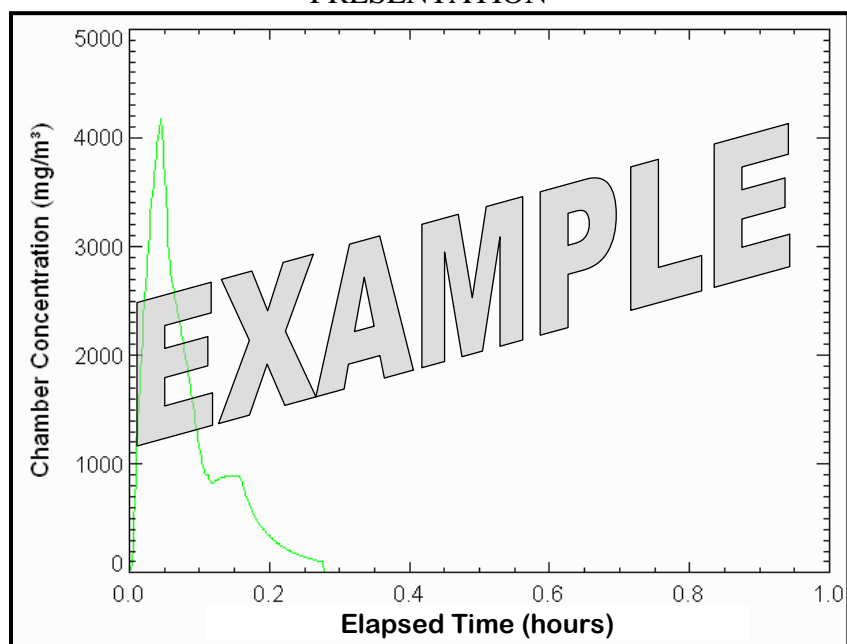
Figure A.6. Example Trial A chamber 24-hour challenge sarin (GB) concentration.



**NOTE:** Mask treated with insect repellent/camouflage cream and contaminated with sarin (GB).

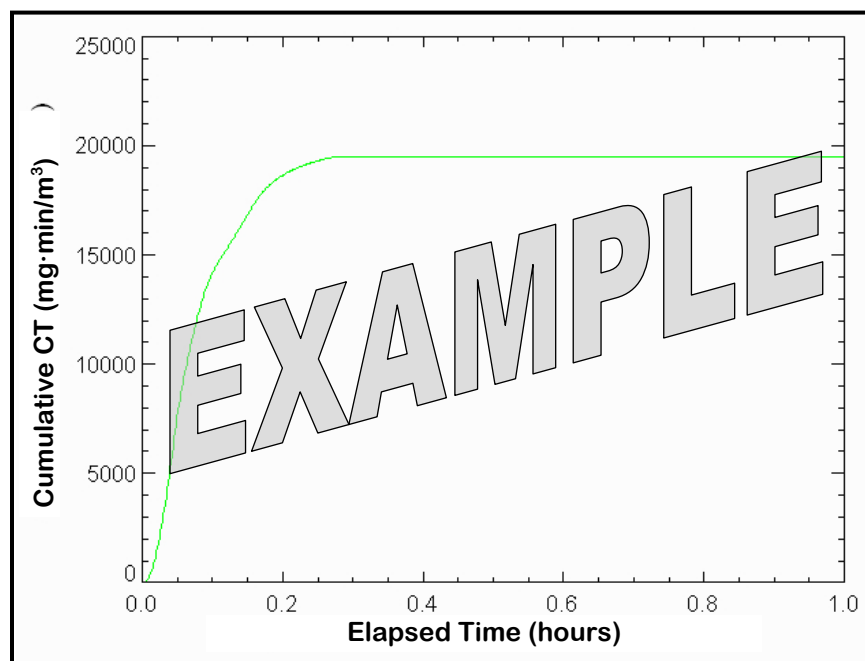
Figure A.7. Example Trial A chamber 24-hour challenge sarin (GB) concentration  $\times$  time (CT).

APPENDIX A. EXAMPLE TABLES, PHOTOGRAPHS, AND GRAPHS FOR DATA  
PRESENTATION



**NOTE:** Mask treated with insect repellent/camouflage cream and contaminated with sarin (GB).

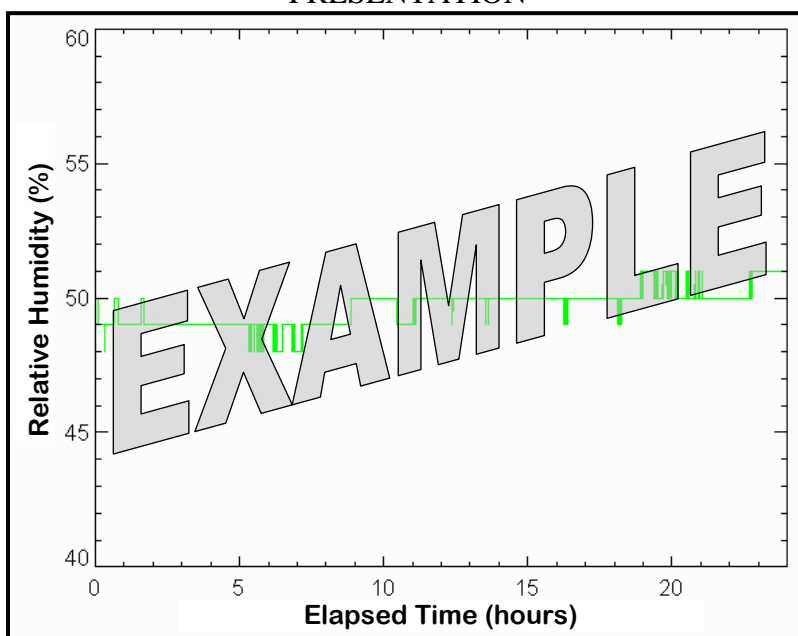
Figure A.8. Example Trial A chamber 1-hour challenge sarin (GB) concentration.



**NOTE:** Mask treated with insect repellent/camouflage cream and contaminated with sarin (GB).

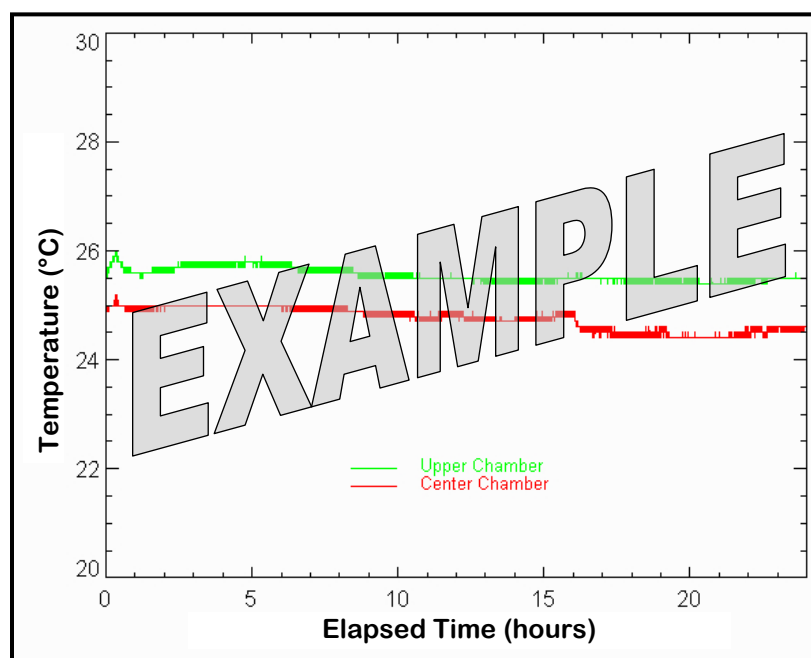
Figure A.9. Example Trial A chamber 1-hour challenge sarin (GB)  
concentration  $\times$  time (CT).

## APPENDIX A. EXAMPLE TABLES, PHOTOGRAPHS, AND GRAPHS FOR DATA PRESENTATION



**NOTE:** Mask treated with Reactive Skin Decontamination Lotion (RSDL) and contaminated with distilled mustard (HD).

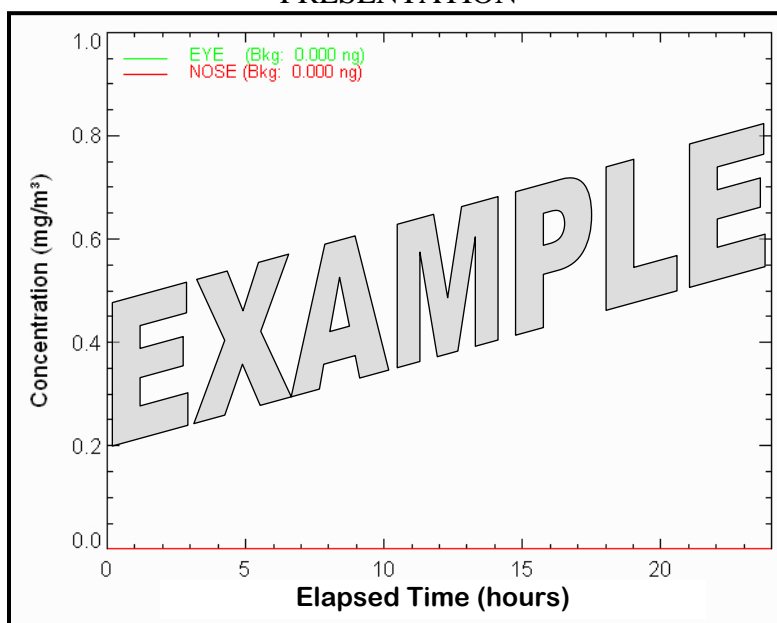
Figure A.10. Example Trial B chamber relative humidity.



**NOTE:** Mask treated with Reactive Skin Decontamination Lotion (RSDL) and contaminated with distilled mustard (HD).

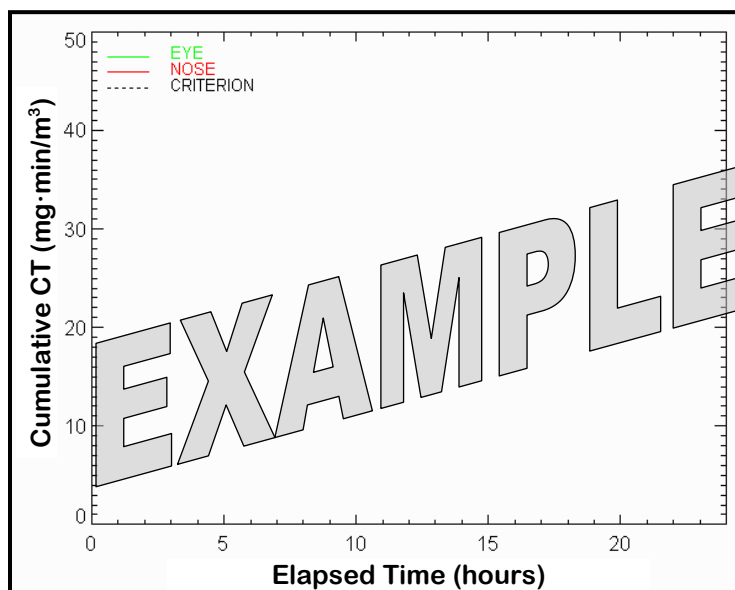
Figure A.11. Example Trial B chamber temperature.

APPENDIX A. EXAMPLE TABLES, PHOTOGRAPHS, AND GRAPHS FOR DATA  
PRESENTATION



**NOTE:** Mask treated with Reactive Skin Decontamination Lotion (RSDL) and contaminated with HD.

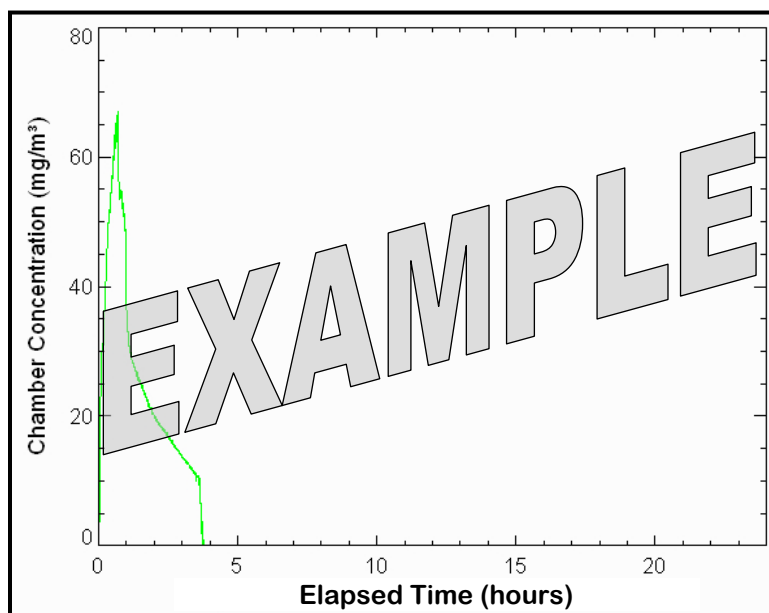
Figure A.12. Example Trial B mask breakthrough 24-hour challenge distilled mustard (HD) concentration.



**NOTE:** Mask treated with Reactive Skin Decontamination Lotion (RSDL) and contaminated with HD.

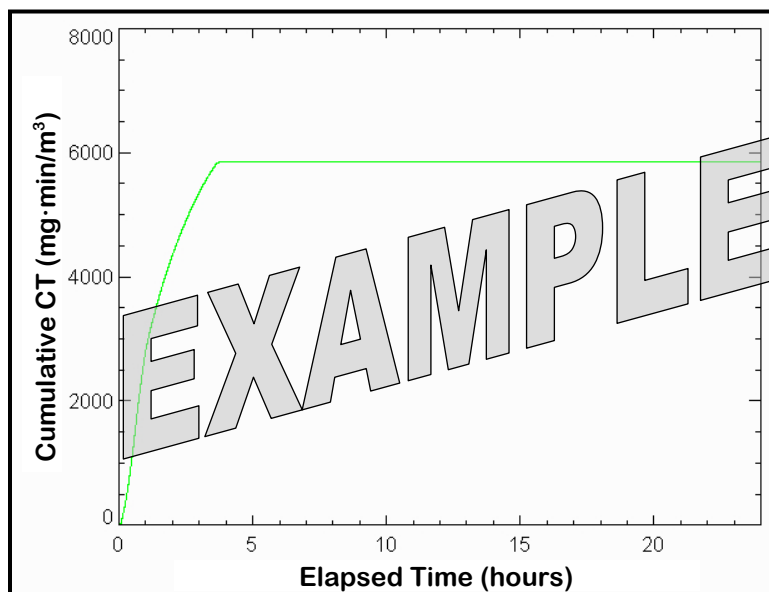
Figure A.13. Example Trial B mask breakthrough 24-hour challenge distilled mustard (HD) cumulative concentration  $\times$  time (CT).

## APPENDIX A. EXAMPLE TABLES, PHOTOGRAPHS, AND GRAPHS FOR DATA PRESENTATION



**NOTE:** Mask treated with Reactive Skin Decontamination Lotion (RSDL) and contaminated with HD.

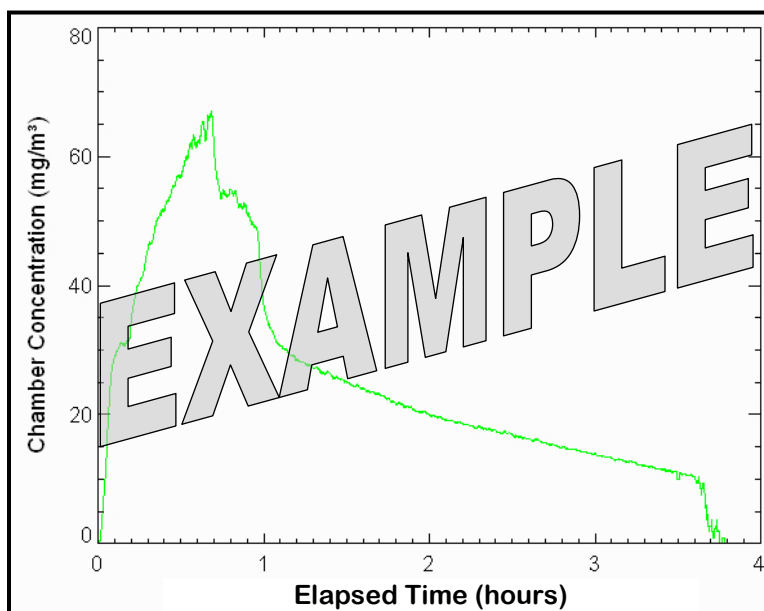
Figure A.14. Example Trial B chamber 24-hour challenge distilled mustard (HD) concentration.



**NOTE:** Mask treated with Reactive Skin Decontamination Lotion (RSDL) and contaminated with HD.

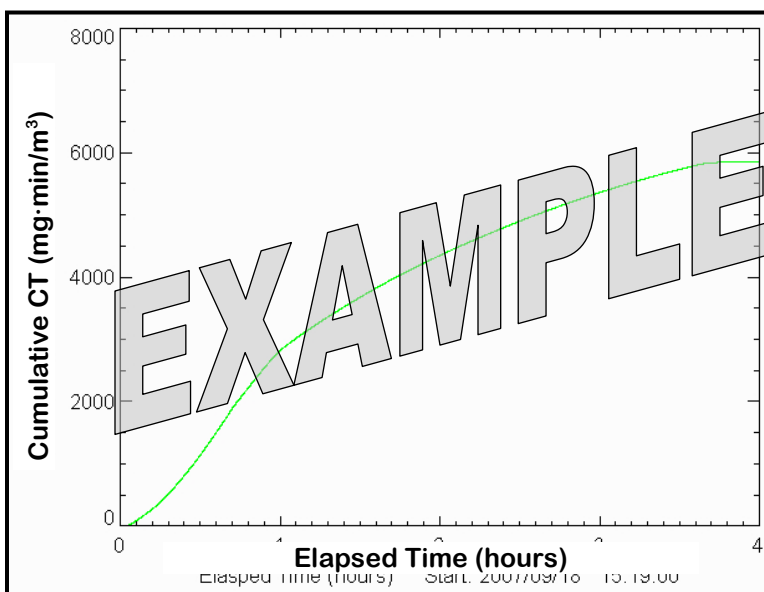
Figure A.15. Example Trial B chamber 24-hour challenge distilled mustard (HD) concentration  $\times$  time (CT).

# APPENDIX A. EXAMPLE TABLES, PHOTOGRAPHS, AND GRAPHS FOR DATA PRESENTATION



**NOTE:** Mask treated with Reactive Skin Decontamination Lotion (RSDL) and contaminated with HD.

Figure A.16. Example Trial B chamber 4-hour challenge distilled mustard (HD) concentration.



**NOTE:** Mask treated with Reactive Skin Decontamination Lotion (RSDL) and contaminated with HD.

Figure A.17. Example Trial B chamber 4-hour challenge distilled mustard (HD) concentration  $\times$  time (CT).

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## APPENDIX B. TEST EQUIPMENT

Thermocouple or equivalent.

Hygrometer or equivalent.

Anemometer or equivalent.

Calibrated syringe pump dispenser or equivalent. Computer-controlled calibrated syringe pump dispenser or equivalent.

Still color camera.

TDA-99 field mask leakage testers (Air Techniques International, Baltimore, Maryland) or equivalent instruments.

Miniature Infrared Analyzer<sup>®</sup> (MIRAN<sup>®</sup>, Thermo Fisher Scientific, Waltham, Massachusetts), MINICAMS<sup>®</sup> (a miniature, automatic, continuous air-monitoring system, OI Analytical, division of OI Corporation, College Station, Texas), sulfur/phosphorus analyzer, or equivalents of these instruments.

Simulant Agent Resistance Test Manikin (SMARTMAN) fixture and exposure chamber, which is constructed to house the test item during agent or simulant dissemination. The fixture/chamber combination will include the environmentally controlled test chamber, agent/simulant liquid and vapor disseminators, manikin head form with breather pump control, and all other instrumentation necessary to perform SMARTMAN testing, including sampling systems and data recorders.

48-mm Teflon<sup>®</sup> polytetrafluoroethylene (PTFE) coupons (DuPont<sup>™</sup>, E.I. du Pont de Nemours and Company, Wilmington, Delaware), or equivalent.

Software for calculations and data recording.

Gas chromatograph (GC), flame photometric detector (FPD), flame ionization detector (FID), liquid chromatograph (LC), mass spectrometer (MS), or equivalents of these instruments.

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## APPENDIX C. ABBREVIATIONS

$\Delta P$	differential pressure
AD No.	accession number
AgF	silver fluoride
AR	Army Regulation
ATEC	U.S. Army Test and Evaluation Command
BFC	battlefield contaminant
CAS	Chemical Abstract Service
CBR	chemical, biological, and radiological
CDD	capability development document
CHWSF	Chemical Hazardous Waste Storage Facility
CONOPS	concept of operations
COTS	commercial off-the-shelf
CPD	capability production document
CPRP	Chemical Personnel Reliability Program
CT	concentration multiplied by time
CWA	chemical warfare agent
DA	Department of the Army
DTP	detailed test plan
EMT	emergency medical technician
FD/SC	failure definition/scoring criteria
FF	fit factor
FID	flame ionization detector
FPD	flame photometric detector
G-agent	nerve agent

## APPENDIX C. ABBREVIATIONS

G-analog	G-series agent from VX breakdown products
GB	sarin
GBV	sarin vapor
GC	gas chromatograph
H-agent	blister agent
HD	distilled mustard
IAW	in accordance with
ICD	initial capabilities document
IP	individual protection
ITOP	international TOP
iwg	inches water gauge
JP-8	jet propulsion fuel type 8
JSMLT	Joint Service Mask Leak Tester
LC	liquid chromatograph
L/V	liquid/vapor
MDL	minimum detection limit
MIL-STD	Military Standard
MINICAMS <sup>®</sup>	a miniature, automatic, continuous air-monitoring system
MIRAN <sup>®</sup>	Miniature Infrared Analyzer <sup>®</sup>
MQL	minimum quantification limit
MS	mass spectrometer
MTOP	multinational TOP
NET	new equipment training
NIOSH	National Institute for Occupational Safety and Health
NRT	near real time
NTA	non-traditional agent

APPENDIX C. ABBREVIATIONS

OEP	OTA evaluation plan
OPSEC	operations security
OTA	operational test agency
PAM	pamphlet
PTFE	polytetrafluoroethylene
QA	quality assurance
QC	quality control
R <sup>2</sup>	correlation value
RDT&E	research, development, test and evaluation
REC	record of environmental consideration
RH	relative humidity
RSD	relative standard deviation
RSDL	reactive skin decontamination lotion
SMARTMAN	Simulant Agent Resistance Test Manikin
SN	serial number
SOP	standing operating procedure
T&E	test and evaluation
TEMP	test and evaluation master plan
TIC	toxic industrial chemical
TICN	test item control number
TOP	test operations procedure
TP	test plan
TRR	test readiness review

APPENDIX C. ABBREVIATIONS

VDLS	VISION Digital Library System
VISION	Versatile Information Systems Integrated Online Nationwide
VX	persistent nerve agent

## APPENDIX D. REFERENCES

1. U.S. Army Test and Evaluation Command (ATEC), Aberdeen Proving Ground, Maryland, Test Operations Procedure (TOP) 08-2-110, Masks, Protective, 1 August 1997.
2. Headquarters, Department of the Army (DA), Washington, DC, Army Regulation (AR) 385-10, The Army Safety Program, 23 August 2007 [Rapid Action Revision (RAR) 004, 4 October 2011].
3. Headquarters, Department of the Army (DA), Washington, DC, Pamphlet (PAM) 385-61, Toxic Chemical Agent Safety Standards, 17 December 2008.
4. Department of Defense (DoD), Washington, DC, Military Standard (MIL-STD)-882E, Standard Practice for System Safety, 11 May 2012.
5. U.S. Army Dugway Proving Ground (DPG), Utah, Standing Operating Procedure (SOP) WDC-ANA-027\*\*, Procedure for the Testing of Protective Equipment in the Simulant Agent-Resistant Test Manikin (SMARTMAN) Exposure Chambers, Revision 9, 5 February 2013.
6. U.S. Army Soldier Systems Command, U.S. Army Natick Research Development and Engineering Center, Natick, Massachusetts, Army Anthropometric Survey Database, NATICK/TR-89/044, Downsizing, Demographic Change and Validity of the 1988 Data in 1996, October 1996.
7. U.S. Army Dugway Proving Ground (DPG), Utah, Standing Operating Procedure (SOP) WDC-ANA-002\*\*, Miniature Infrared Analyzer (MIRAN<sup>®</sup>) Calibration and Operation, Revision 9, 21 May 2013.
8. U.S. Army Dugway Proving Ground (DPG), Utah, Standing Operating Procedure (SOP) WDC-QAC-003R\*\*, Chemical Hazardous Waste Storage Facility (CHWSF) Quality Assurance Program Plan, Revision 4, 11 February 2013.
9. U.S. Army Test and Evaluation Command (ATEC), Aberdeen Proving Ground, Maryland, Test Operations Procedure (TOP) 08-2-500, Receipt Inspection of Chemical-Biological (CB) Materiel, 7 January 1984.
10. U.S. Army Dugway Proving Ground (DPG), Utah, Standing Operating Procedure (SOP) WDC-ANA-034\*\*, Near Real-Time Chemical Agent Monitoring, Revision 8, 25 September 2012.
11. U.S. Army Dugway Proving Ground (DPG), Utah, Standing Operating Procedure (SOP) DP-0000-M-073\*\*, Preparation and Verification Procedures for First Dilution, Stock A and Working Solutions, Revision 14, Change 1, 12 March 2013.

#### APPENDIX D. REFERENCES

12. U.S. Army Dugway Proving Ground (DPG), Utah, Standing Operating Procedure (SOP) WDC-ANA-031\*\*, Chemical Purity Analysis and Certification, Revision 8, 25 March 2013.
13. U.S. Army Dugway Proving Ground (DPG), Utah, Standing Operating Procedure (SOP) WDC-ANA-012\*\*, Mixing Additives Into Chemical Agents, Revision 10, 6 April 2013.
14. Headquarters, Department of the Army (DA), Washington, DC, Department of the Army (DA) Pamphlet (PAM) 73-1, Test and Evaluation in Support of Systems Acquisition, 30 May 2003.
15. U.S. Army Test and Evaluation Command (ATEC), Aberdeen Proving Ground (APG), Maryland, ATEC Pamphlet (PAM) 73-1, Volumes I and II, System Test and Evaluation Procedures and Developing, Classifying, and Reporting Test and Evaluation Documents, 9 July 2013.

\*\* SOPs are included only to serve as examples of the types of procedures that are used at U.S. Army Dugway Proving Ground and as a reference for other installations. Many SOPs are specific to a particular installation, facility, or instrument, and may not be applicable between different installations, facilities, or instruments without modifications. It is expected that installations will have their own equivalent SOPs. These equivalent SOPs must be provided to the Test & Evaluation (T&E) community interested in this test method in order to properly understand the data produced, any differences between test method application between installations, and therefore, the ability to compare data produced by different installations. If an installation does not have an equivalent SOP already in place, these or other similar procedures could be used as temporary guides until appropriate SOPs are developed. The most current version of these SOPs can be requested through U.S. Army Test and Evaluation Command (ATEC) or through access to Versatile Information Systems Integrated Online Nationwide (VISION) Digital Library System (VDLS).



#### For information only (related publications)

- a. Headquarters, Department of the Army, Washington, D.C., Army Regulation (AR) 50-6, Nuclear and Chemical Weapons and Materiel, Chemical Surety, 28 July 2008.
- b. Headquarters, Department of the Army, Washington, D.C., Army Regulation (AR) 190-59, Military Police, Chemical Agent Security Program, 11 September 2006.



## APPENDIX E. APPROVAL AUTHORITY

The Individual Protection (IP) Capability Area Process Action Team (CAPAT) of the Test and Evaluation Capabilities and Methodologies Integrated Process Action Team (TECMIPT) has completed review of this document. The CAPAT recommends approval of this document. If a representative non-concurs, a dissenting position paper will be attached.

Concurrence Sheet for the Test Operations Procedure (TOP) 08-2-109, Simulant Agent Resistance Test Manikin (SMARTMAN) Testing of Protective Masks	
Lt Col Kevin Reilly US Marine Corps Operational Test & Evaluation Activity (MCOTEA)  Signature Date <u>6 May 13</u>	Steven Tackett US Army Test and Evaluation Command (ATEC)/US Army Evaluation Center (AEC)  Signature Date <u>19 Nov 2012</u>
Nevin K. Elden, USAF Director of Operations US Air Force Operational Test and Evaluation Center (AFOTEC)  Signature Date <u>31 Oct 12</u>	Laurie K. Richter, Lt Col, USAF Joint Requirements Office (JRO) for Chemical, Biological, Radiological, and Nuclear Defense  Signature Date <u>23 May 13</u>
Jeffery Bobrow Assistant Chief of Staff, Expeditionary Warfare, Commander Operational Test and Evaluation Force (COMOPEVFOR)  Signature Date <u>13 Dec 2012</u>	Deborah Shuping CBRN Defense (CBRND) T&E Executive  Signature Date <u>11/9/12</u>
Curt Wilhide Joint Program Executive Office for Chemical and Biological Defense (JPEO CBD)  Signature Date <u>12 May 2013</u>	Mike Roberts Joint Science and Technology Office (JSTO)  Signature Date _____
Charlie Walker Individual Protection CAPAT Chair  Signature Date <u>130409</u>	

Note: CAPAT members' Signature represents an O6 level concurrence from their organization. If the CAPAT representative is not empowered at this level, he/she must coordinate the concurrence/non-concurrence process within his/her organization, and prior to the specified suspense date for the document.

APPENDIX E. APPROVAL AUTHORITY

T&E Capabilities and Methodologies Integrated Process Team (TECMIPT) Chair Endorsement

AMXAA-CD

10 June 2013

MEMORANDUM FOR

Chemical, Biological, Radiological and Nuclear Defense (CBRND) Test and Evaluation (T&E) Executive, Office of the Deputy Under Secretary of the Army, Taylor Building, Suite 8070, 2530 Crystal Drive, Arlington, VA 22202

SUBJECT: Test and Evaluation Capabilities and Methodologies Integrated Process Team (TECMIPT) Test Operations Procedure (TTOP) 8-2-109, Simulant Agent Resistance Test Manikin (SMARTMAN) Testing of Protective Masks

1. The Individual Protection Capability Area Process Action Team (CAPAT) has completed their review of the subject TTOP in accordance with the DUSA-TE Instructions to the TECMIPT, the Standards and Development Plan, and the TECMIPT Standard Operating Procedure (SOP). All signatory members of the CAPAT have provided their concurrence to this TTOP. The CAPAT signature sheets and the ATEC Approval for Publication memorandum are enclosed.
2. Based on the concurrence of the CAPAT, I recommend the CBRND T&E Executive endorse this TTOP as a Department of Defense (DoD) Test and Evaluation (T&E) Standard.

Encl



RONALD O. PRESCOTT  
TECMIPT Chair

APPENDIX E. APPROVAL AUTHORITY

Deputy Under Secretary of the Army Endorsement



DEPARTMENT OF THE ARMY  
OFFICE OF THE DEPUTY UNDER SECRETARY OF THE ARMY  
102 ARMY PENTAGON  
WASHINGTON, DC 20310-0102

DUSA-TE

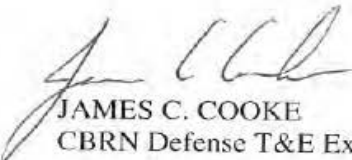
OCT 24 2013

MEMORANDUM FOR DISTRIBUTION

SUBJECT: Endorsement of TECMIPT Test Operations Procedure (TTOP) 08-2-109, Simulant Agent Resistance Test Manikin (SMARTMAN) Testing of Protective Mask Systems

1. Reference: Memorandum, DUSA-TE, 19 July 10, subject: Chemical and Biological Defense Program (CBDP) Test and Evaluation (T&E) Standards Development Plan.
2. I endorse TTOP 08-2-109 as a DoD T&E Standard for protective mask testing and encourage its broad use across all test phases.
3. All T&E Standards are for government associated program access and use. They are stored in Army Knowledge Online (AKO), located at <https://www.us.army.mil/suite/files/22142943> and on the National Institute of Standards and Technology (NIST) website at <http://gsi.nist.gov/global/index.cfm/L1-4/L2-19/A-664>.
4. My point of contact for this action is Ms. Deborah Shuping, (703) 545-1119, [deborah.f.shuping.civ@mail.mil](mailto:deborah.f.shuping.civ@mail.mil).

Encl

  
JAMES C. COOKE  
CBRN Defense T&E Executive

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APPENDIX E. APPROVAL AUTHORITY

Deputy Under Secretary of the Army Endorsement

DUSA-TE

SUBJECT: Endorsement of TECMIPT Test Operations Procedure (TTOP) 08-2-109, Simulant Agent Resistance Test Manikin (SMARTMAN) Testing of Protective Mask Systems

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Commander, NSWC-DD

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APPENDIX E. APPROVAL AUTHORITY

CSTE-TM

16 September 2013

MEMORANDUM FOR

Commanders, All Test Centers  
Technical Directors, All Test Centers  
Directors, U.S. Army Evaluation Center  
Commander, U.S. Army Operational Test Command

SUBJECT: Test Operations Procedure (TOP) 08-2-109, Simulant Agent Resistance Test Manikin (SMARTMAN) Testing of Protective Mask Systems, Approved for Publication

1. TOP 08-2-109, Simulant Agent Resistance Test Manikin (SMARTMAN) Testing of Protective Mask Systems, has been reviewed by the U.S. Army Test and Evaluation Command (ATEC) Test Centers, the U.S. Army Operational Test Command, and the U.S. Army Evaluation Center. All comments received during the formal coordination period have been adjudicated by the preparing agency. The scope of the document is as follows:

This TOP is intended to furnish basic testing information to facilitate test planning, conducting and reporting, and to achieve standardized chemical protective performance testing of protective masks and accessories using the Simulant Agent Resistance Test Manikin (SMARTMAN). It describes test facilities, equipment, and procedures to be used for SMARTMAN testing and evaluating protective mask technical performance and safety aspects. Biological and radiological protective performance testing of the mask systems is not included in this TOP.

2. This document is approved for publication and has been posted to the Reference Library of the ATEC Vision Digital Library System (VDLS). The VDLS website can be accessed at <https://vdls.atc.army.mil/>.

3. Comments, suggestions, or questions on this document should be addressed to U.S. Army Test and Evaluation Command (CSTE-TM), 2202 Aberdeen Boulevard-Third Floor, Aberdeen Proving Ground, MD 21005-5001; or e-mailed to [usarmy.apg.atec.mbx.atec-standards@mail.mil](mailto:usarmy.apg.atec.mbx.atec-standards@mail.mil).

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c=US  
Date: 2013.08.16 08:57:50 -0400

MICHAEL J. ZWIEBEL  
Director, Test Management Directorate (G9)

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Forward comments, recommended changes, or any pertinent data, which may be of use in improving this publication to the following address: Range Infrastructure Division (CSTE-TM), US Army Test and Evaluation Command, 2202 Aberdeen Boulevard, Aberdeen Proving Ground, Maryland 21005-5001. Technical information may be obtained from the preparing activity: Commander, West Desert Test Center, U.S. Army Dugway Proving Ground, ATTN: TEDT-DPW, Dugway, UT 84022-5000. Additional copies can be requested through the following website: <http://www.atec.army.mil/publications/topsindex.aspx>, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.